Coarseness of MRI Texture in Acute lesions Relates to Subsequent Recovery Activity in Multiple Sclerosis

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Introduction

A dynamic sequence of inflammatory, degenerative, and restorative processes is proposed in multiple sclerosis (MS) that causes the pathological mixture of inflammation, demyelination, axonal loss, and remyelination. From MRI perspective, lesion pathogenesis typically starts with acute gadolinium (Gd) enhancement, followed by chronic hyperintensity on T2-weighted (T2w) MRI. T2 hyperintensity is considered pathologically non-specific, however, little is known about which pathological processes are possibly dominating the T2 signal captured at a single snapshot. Texture analysis using the polar Stockwell Transform (PST)[1] demonstrates promise in detecting subtle signal alterations on conventional MRI. PST spectral energy increases represent inflammation and demyelination in mice.[2] Changes on the sum of low frequency energy (sumLFE) are marked in the deep gray matter over time on treatment in MS.[3] We hypothesize that specific tissue pathology gives rise to unique MRI texture signatures. This project was to characterize texture properties within acute new MS lesions in relation to recovery 8 months after on T2w MRI.

Subjects and Methods

Twenty untreated relapsing-remitting MS patients were scanned bi-monthly for twelve months on a 1.5T Siemens 63SP MR System. Eligible Patients were selected if they had at least one new Gd-enhancing lesion (defined as month 0) arising from NAWM on the previous scan (month -2). The inactive region was analyzed 8 months post-enhancement. Identified lesions were classified based on their appearance on T2w MRI at month 8 as either invisible (no hyperintensity) or persisting (hyperintense). T2w MRI was acquired using a FSE sequence (TR/TE=2270/80ms, FOV=25cm^2, matrix size=256x256, slice thickness=3mm). Gd-enhancing MRI was obtained by a SE sequence 5 minutes after gadolinium injection. Serial T2w MRI were co-registered[4] to align sequential images for each patient after image non-uniformity correction.[5] Regions of interest (ROIs) were placed around active lesions on T2w MRI and then superimposed onto the co-registered MRI to ensure that the same area was measured. The PST spectra were computed for each pixel in a ROI. The mean local one-dimensional spectrum[3] of the central 5 x 5 pixels in a ROI was obtained for analysis. The sumLFE within a range of 0 < frequency ≤ 2.88 cm^{-1} was also calculated. Texture difference was assessed using a two-way non-parametric ANOVA. Significance level was at P≤0.05.

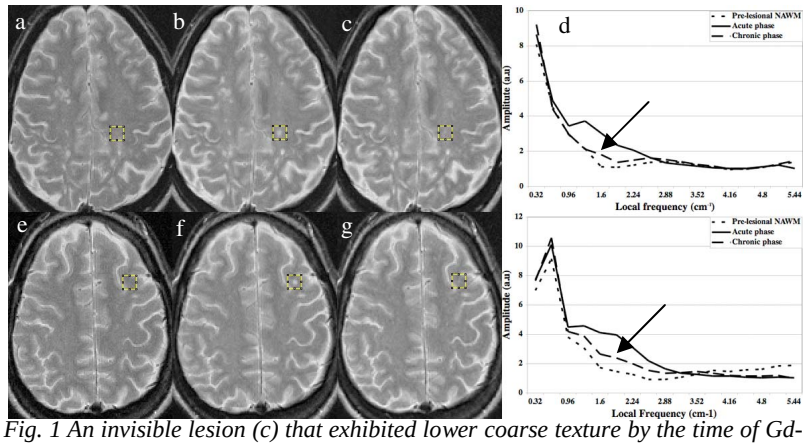

Fig. 1 An invisible lesion (c) that exhibited lower coarse texture by the time of Gd-enhancement (a,b) resulted in better spectral recovery (d, arrow) than that in a persisting lesion (e,f,g,h, arrow).

Results

Twelve lesions from 10 MS patients met the selection criteria. Five/12 were invisible and 7/12 persisted on T2w MRI at month 8. Spectral evolution patterns differed between persisting and invisible lesions over time (Fig. 1). The average sumLFE in persisting lesions was significantly higher (P<0.05) than that in the invisible lesions in pre-lesional NAWM (by 60.4%), during the acute phase (by 70.4%), and at the chronic phase (by 65.8%) (Fig. 2). The difference on sumLFE was not statistically significant between lesion states in either group, perhaps due to the small sample size (P>0.05).

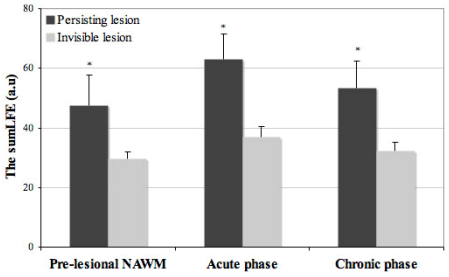

Fig. 2 Significantly higher (*) coarse texture in persisting lesions than in the invisible ones began in the pre-lesional NAWM, peaked at acute phase, and extended to chronic phase.

Discussions and Conclusions

This preliminary study showed that lesions with higher sumLFE recovered less than lesions of lower sumLFE. The PST modulates dominant signal changes in a ROI. Generally, low frequency means coarse texture and high frequency represents fine texture. Inflammation, demyelination, and axonal injury in acute lesions[6] may increase the complexity of tissue structure and image texture, whereas resolution of inflammation and remyelination improves the regularity of tissue structure and reduces the coarseness of local texture. The significantly higher sumLFE in persisting lesions starting 2 months before Gd-enhancement may be due to more severe tissue damage. It seems to predict less subsequent recovery than occurs in invisible lesions. Ongoing evaluation of changes in matched, contralateral NAWM will determine changes in tissue unaffected by an episode of acute inflammation. While this study warrants further investigation, this novel texture analysis approach may be useful in predicting lesion recovery by analyzing the coarseness of lesion texture on conventional T2w MRI in MS. This technique may also facilitate evaluation of therapies that aim to provide neuroprotection or enhance repair.

References 1. Zhu et al., *Med Phys* 2003;30:1134-41. 2. Zhang Y, et al., *MICCAI* 2006;4190:760-767. 3. Zhang Y, et al., *RSNA* 2007. 4. Jenkinson M, et al. *NeuroImage* 2002;17:825-841. 5. Sled J, et al., *IEEE TMI* 1998;17:87-97. 6. Pittock SJ, et al., *Neurologist* 2007;13:45-56.